Design and Simulation of 2.4 GHz Microstrip Antenna

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***Abstract*— As a result of developments in communication systems in recent decades, the need for smaller, more lightweight, and higher-performance antennas has increased. One of the leading antenna types that can meet these needs is microstrip antennas. They provide many advantages such as their small size, easy to manufacture, and low cost. In addition to these advantages, they also have weaknesses such as low bandwidth. In this study, a rectangular microstrip patch antenna operating at 2.4 GHz resonance frequency is constructed. The antenna is designed on FR-4 substrate with a thickness of 1.6 mm and dielectric constant εr=4.4. It has three slots. Two on the patch and one on the ground plane. Desired patch antenna design is simulated by CST. The return loss of the designed antenna is –43 dB, and its bandwidth is 70 MHz.**

Keywords—2.4 GHz, microstrip patch antenna, bandwidth, CST Microwave Studio, return loss

I. Introduction

Antenna is a key device element in transmitting and receiving signals. Due to their appealing qualities such as light weight, easy fabrication, cheap cost, and compatibility with planar monolithic microwave integrated circuit (MMIC) components, microstrip patch antennas are preferred in wireless communication systems [1].

The most common band type used for microstrip patch antennas in home, office, and industrial applications is ISM (Industrial, Scientific, and Medical) band with 2400-2485 MHz. IEEE (Institute of Electrical and Electronics Engineers) the wireless network developed by WLAN (Wireless Local Area Network) the general name of the standard is IEEE 802.11 and the ISM wireless LAN operating in the 2.4 GHz band the standard is defined as IEEE 802.11b and IEEE 802.11g. Although there are the same differences between them, basically the 802.11 family uses the same protocols. In the literature, microstrip patch many studies have been carried out to increase the bandwidth and gain of antennas [2,4]. The essential microstrip receiving wire component involves a metal fix upheld over a bigger ground plane. The fix is normally printed on a microwave substrate material with relative permittivity in the range 2 to 10. Yet an assortment of materials might be utilized, contingent upon the application.

Air or low-thickness froths normally offer the lowest loss and most elevated radiation productivity, but higher permittivity substrates result in smaller components with more extensive radiation designs [5]. The conducting patch is the key component of the microstrip antenna (MSA) that impacts antenna performance by modifying return loss, surface current distribution, band-width, impedance matching, harmonic suppression property and radiation pattern [6][7]. Essentially, the traditional structure of MSAs come about a metal radiating patch aspect that is on top of a grounded dielectric substrate of precise thickness [8].

II. Design of Antenna

In order to calculate the patch sizes of the antenna operating at the targeted frequency, several parameters must be determined beforehand. These are the antenna's resonance frequency ”fo”, the substrate thickness “h”, and the dielectric constant of the substrate material “εr” . In this study, FR-4 with relative dielectric constant εr=4.4, height h=1.6 mm are chosen as suitable substrate materials, and ground thickness is chosen as t=35 µm. In this study, it is aimed to reduce the return loss by keeping h, εr, fo as constant and by optimizing other parameters. With the specified parameters, the patch width (Wp) is calculated using equation (1) as follows,

$$W_p = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where:
c = free-space velocity of light.
f_o = resonance frequency.
ε_r = dielectric constant.

Since microstrip antennas do not have a homogeneous structure, it causes a change in the electrical transmittance value. ε_{reff} is calculated by equations (2) and (3).

$$\frac{W_p}{h} > 1 \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W_p}\right]^{-\frac{1}{2}} \quad (3)$$

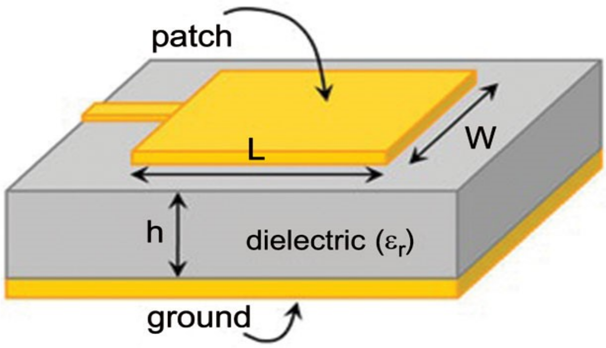


Fig. 1. Microstrip patch antenna

L_{eff} is the effective length of the patch and ΔL represents the length augmentation calculated by equations (4) and (5).

$$L_{eff} = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} \quad (4)$$

$$\Delta L = \frac{0.412h(\varepsilon_{reff}+0.3)\left(\frac{W_p}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W_p}{h}+0.8\right)} \qquad (5)$$

The reel length L_p of the patch is then calculated by the following equation (6).

$$L_p = L_{eff} - 2\Delta L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad (6)$$

As a result, Wp=38 mm, Lp=29.5 mm are found. The width of the ground plane is determined as Wg=76 mm and the length as Lg=59 mm. Microstrip feeding method is used as the feeding method and the length of the transmission line is optimized as 14.75 mm and the thickness as 3.147 mm. The width of the transmission line is determined by changing it according to the impedance match. Two symmetrical slots are made on the patch surface of the antenna. By changing the slot dimensions, the antenna is provided to operate at the desired resonance frequency and the return loss is reduced.

Another slot was opened on the ground plane. By changing the size of the slot opened on the ground plane, optimum value for the antenna performance was found. The length of the opened 17.93mm. The simulations of the designed antenna are carried out on the CST Studio Suite.

III. Results and Discussion

In the simulation of the designed microstrip antenna, optimized results were obtained by changing the slot dimensions and the thickness of the microstrip feeding line and by keeping other parameters constant. Results such as Return Loss, Gain, VSWR, Radiation Pattern were studied between 2 GHz and 2.8 GHz. Analysis results are shown with figures. The length of the slot was optimized by increasing from 1 mm to 59 mm by changing the length 1 mm in each step. The best performing result is obtained when the length of the slot is 17.93 mm. The return loss value is obtained

-44.78 dB, although the bandwidth is not very wide at the resonance frequency. It has been observed that the bandwidth at -10 dB is 70 MHz. The proposed antenna resonant ranges are between 2.36 MHz and 2.43 MHz. The mentioned results are shown in Table 2 and S-parameters shown in Fig.3.

It is shown in Fig.4 that the VSWR value of the designed antenna is 1.013 dB.

Radiation pattern, the antenna radiated is a graph showing the angular change of the power (electromagnetic field strength) at a fixed distance, which is created in the specific far area of the antenna. As seen Fig.5, for phi=90 at 2.4 GHz, the main lobe amplitude 4.7 dB and 3dB angular bandwidth (HPBW) for 107.3° and theta = 90 amplitude of the main lobe 0.778 dB and 3 dB angular bandwidth (HPBW) is 148.3°. The gain at resonance frequency 2.4 GHz is 4.702 dB. These values are powerful according to the literature.

IV. Conclusions

This paper made a review on improving the performance of the 2.4 GHz antenna. It has been observed that this antenna can be used in modern communication. The return loss has been measured to be quite efficient and its gain can be considered sufficient according to the literature. Furthermore, the bandwidth of the antenna is 2.91% of the resonant frequency.

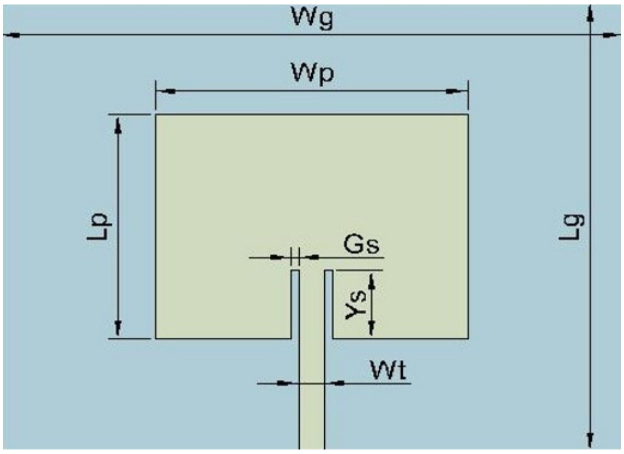


Fig. 2. Patch

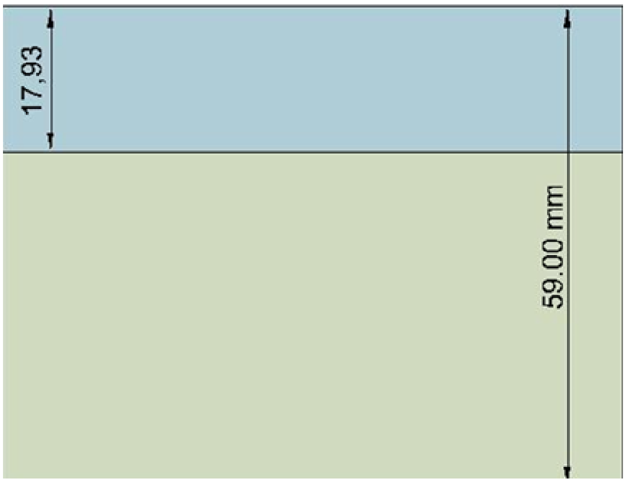


Fig. 3. Ground plane of antenna

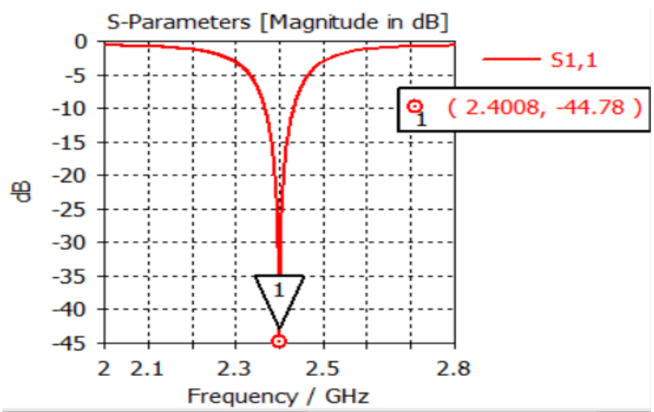


Fig. 4. S-Parameters

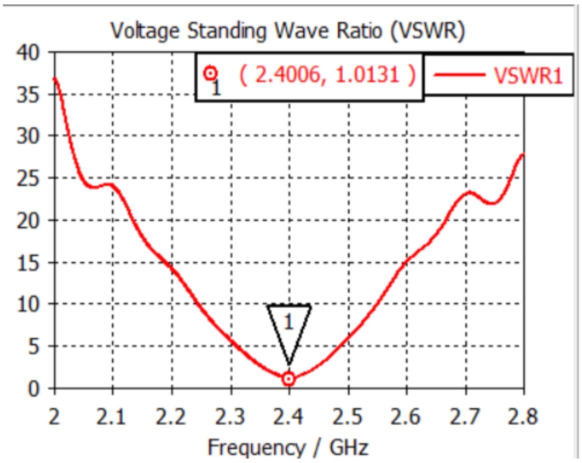
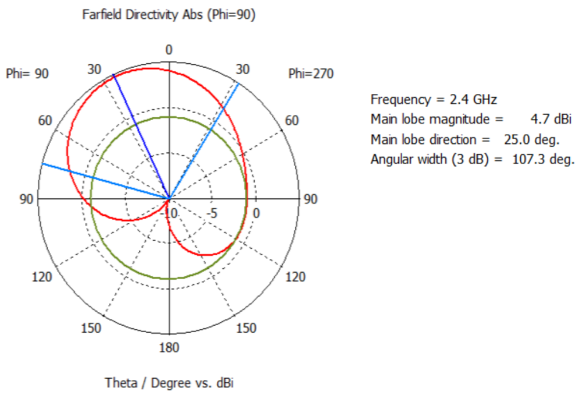
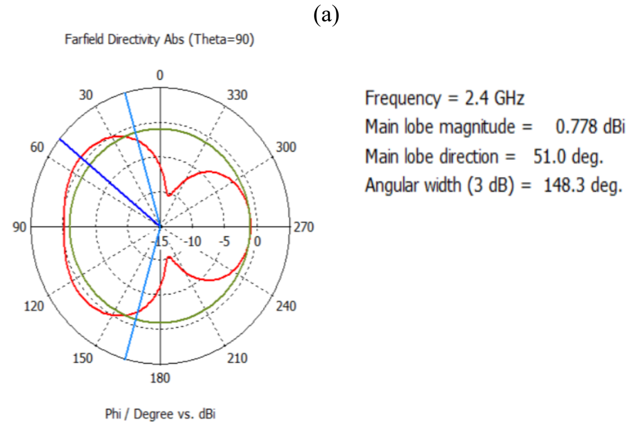


Fig. 5. VSWR simulation result



(a)



(b)

Fig. 6. a) phi=90 radiation pattern b) theta=90 radiation pattern

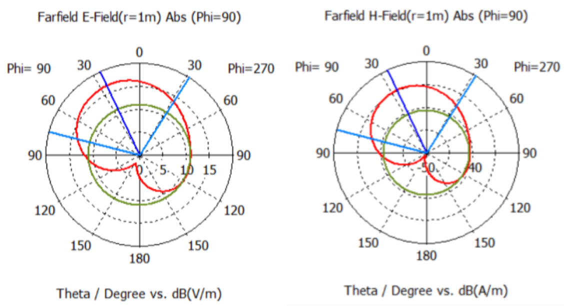


Fig. 7. Directivity at 2.4GHz E-plane and H-plane

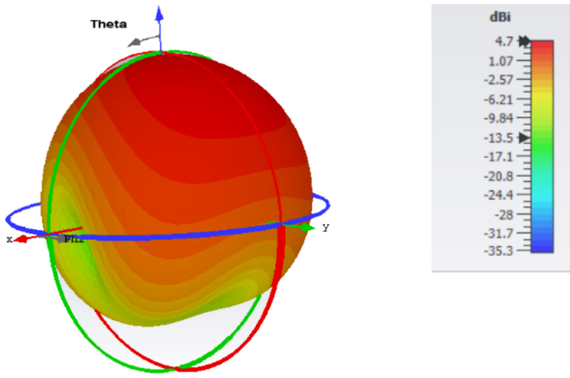


Fig. 8. Farfield of antenna

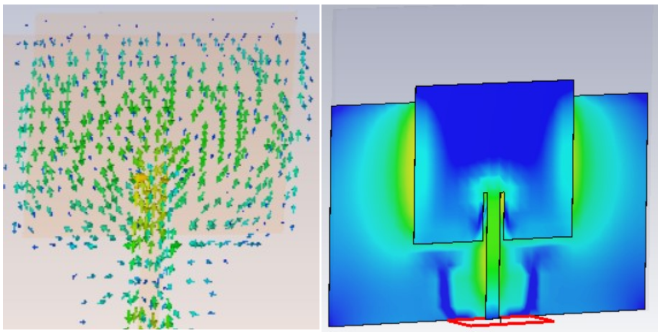


Fig. 9. Surface current at 2.4 GHz

TABLE I. ANTENNA PARAMETERS

parameter	value
fo	2,4 GHz
er	4,4
h	1,6 mm
Wg	76 mm
Lg	59 mm
Wp	38 mm
Lp	29,5 mm
Gs	0,93mm
Ys	8,97 mm
Wt	3,14 mm
t	0,035 mm

TABLE II. RETURN LOSS AND BANDWIDTH

Resonant frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
2.4	-44.78	70

TABLE III. DIRECTIVITY

Resonant Frequency (GHz)	Directivity in E-plane (dB)	Directivity in H-plane (dB)
2.4	4.702	4.702

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